



**National
Transportation
Safety Board**

NTSB Update: Maintenance- Related Accidents

Christopher A. Hart
Vice Chairman

Major Maintenance Issues

- Human Factors awareness
- Quality of maintenance and inspections
- Training

But First – NTSB 101

- Independent agency, investigate transportation accidents, all modes
- Determine probable cause(s) – but not blame or liability – and make recommendations to prevent recurrences
- ***SINGLE FOCUS IS SAFETY***
- Primary product: Safety recommendations
 - Not a regulator, cannot require anything, but recommendation acceptance rate > 80%

Human Factors in Maintenance

- FAA AMT Handbook 8083-30
- Addendum, Chapter 14
- Mx errors: Missing parts, parts installed incorrectly, checks not performed
- Human Factors
 - 80 percent of mx errors
 - Fatigue, complacency, stress, etc.

Human Factors in Maintenance

THE DIRTY DOZEN

Twelve human factors for aircraft maintenance proficiency

Lack of Communication

Lack of Teamwork

Lack of Assertiveness

Complacency

Fatigue

Stress

Lack of Knowledge

Lack of Resources

Lack of Awareness

Distraction

Pressure

Norms

FAA AMT Handbook 8083-30

Discussion of Accident Cases

- Completed cases: common causes, factors, and scenarios
- Missed opportunities to prevent the accident
- What we can learn

Accident: Beech 36

- Pilot/owner planned personal round-trip night IFR flight
- Complete engine power loss on return leg
- Forced landing, pilot fatal

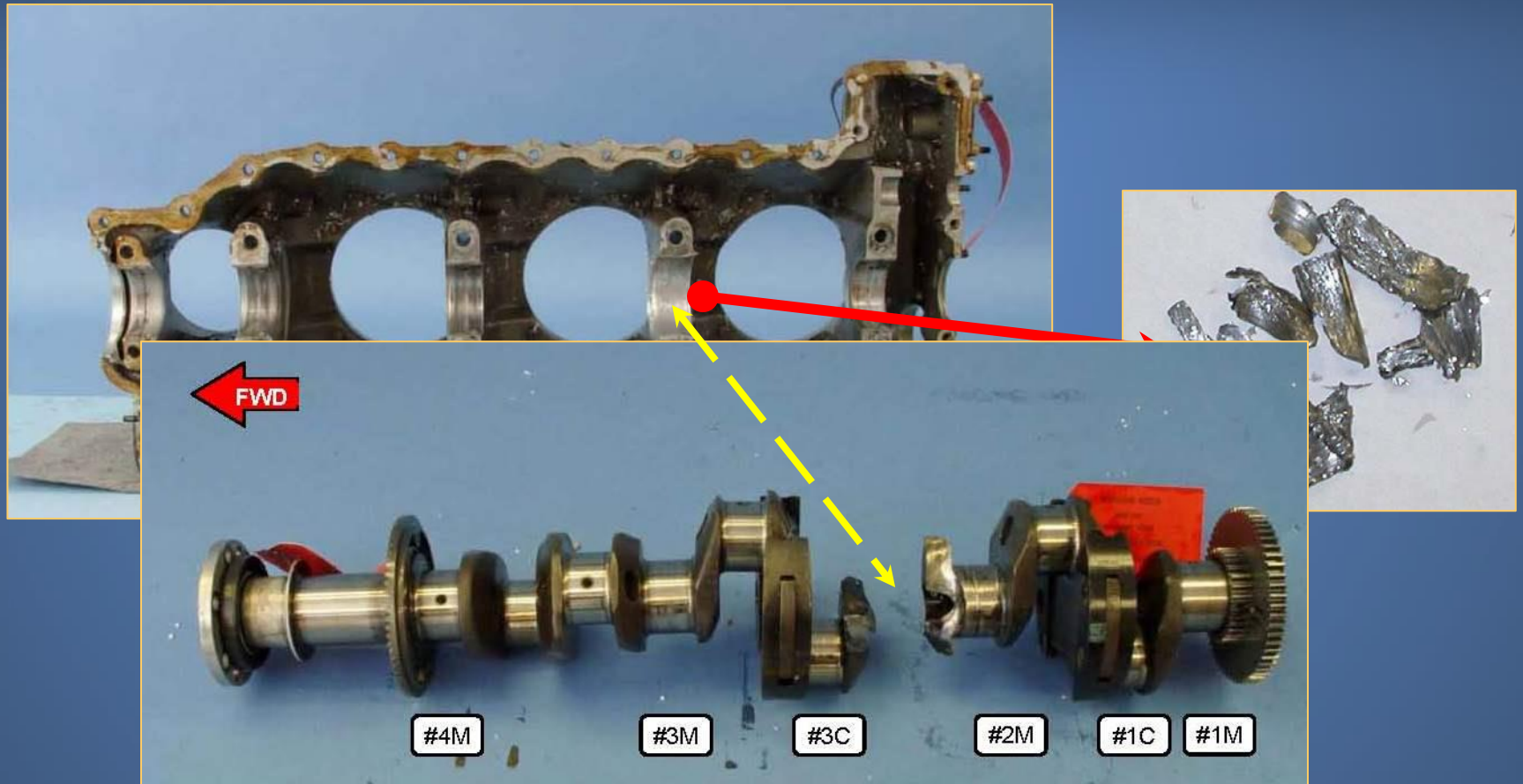
Airplane History

- Engine with 10 hours SMOH when purchased, then pilot flew it about 40 hours prior to accident
- Engine oil pressure problem several weeks before accident
- Mechanic: Overhaul issue
- 1 week later, pilot said engine “seemed OK,” said it was filter
- No evidence of corrective actions

Accident Flight

- No outbound leg problem reports
- Return leg: midnight taxi out, return to FBO to request mechanic (unavailable until morning), so pilot departed – IFR
- Complete loss of power 9 miles from destination, night IMC forced landing on a golf course
- Engine examination: crankshaft fracture

Engine Examination



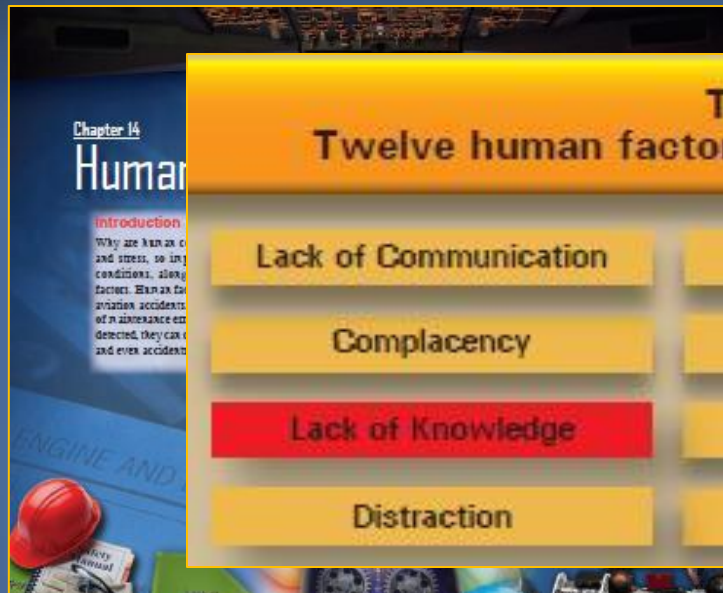
Engine Examination

- Evidence of gasket-making material, silk thread on main bearing bosses
- TCM Service Information Letter (SIL) 99-2B discusses case threading

What We Can Learn

- Follow manufacturer's instructions
- Use up-to-date materials, ask questions if unfamiliar
- Best practices for human factors:
Eliminate fatigue, pressures, etc.

What We Can Learn



THE DIRTY DOZEN Twelve human factors for aircraft maintenance proficiency		
Lack of Communication	Lack of Teamwork	Lack of Assertiveness
Complacency	Fatigue	Stress
Lack of Knowledge	Lack of Resources	Lack of Awareness
Distraction	Pressure	Norms

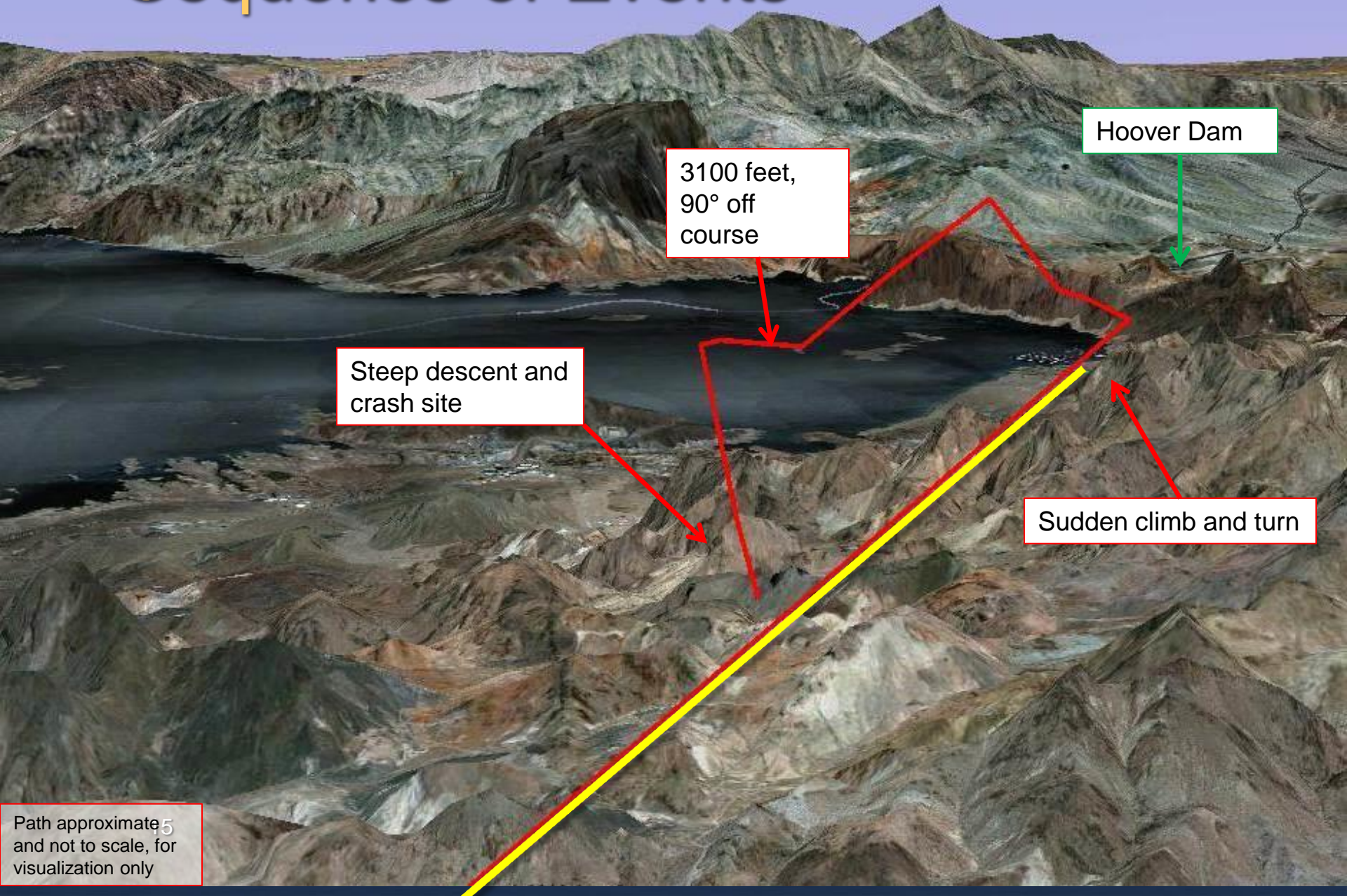
MITIGATING THE RISK		
Only fix parts that you are trained to fix.	Ensure that the maintenance manual you are using is up to date.	If you do not know how to fix something, ask for help from someone who does.



Accident: Eurocopter AS 350B2

- Sightseeing tour from Las Vegas to Hoover Dam
- Normal departure - VFR
- Calm wind, good visibility
- Standardized route

Sequence of Events



Hoover Dam

3100 feet,
90° off
course

Steep descent and
crash site

Sudden climb and turn

Path approximate
and not to scale, for
visualization only

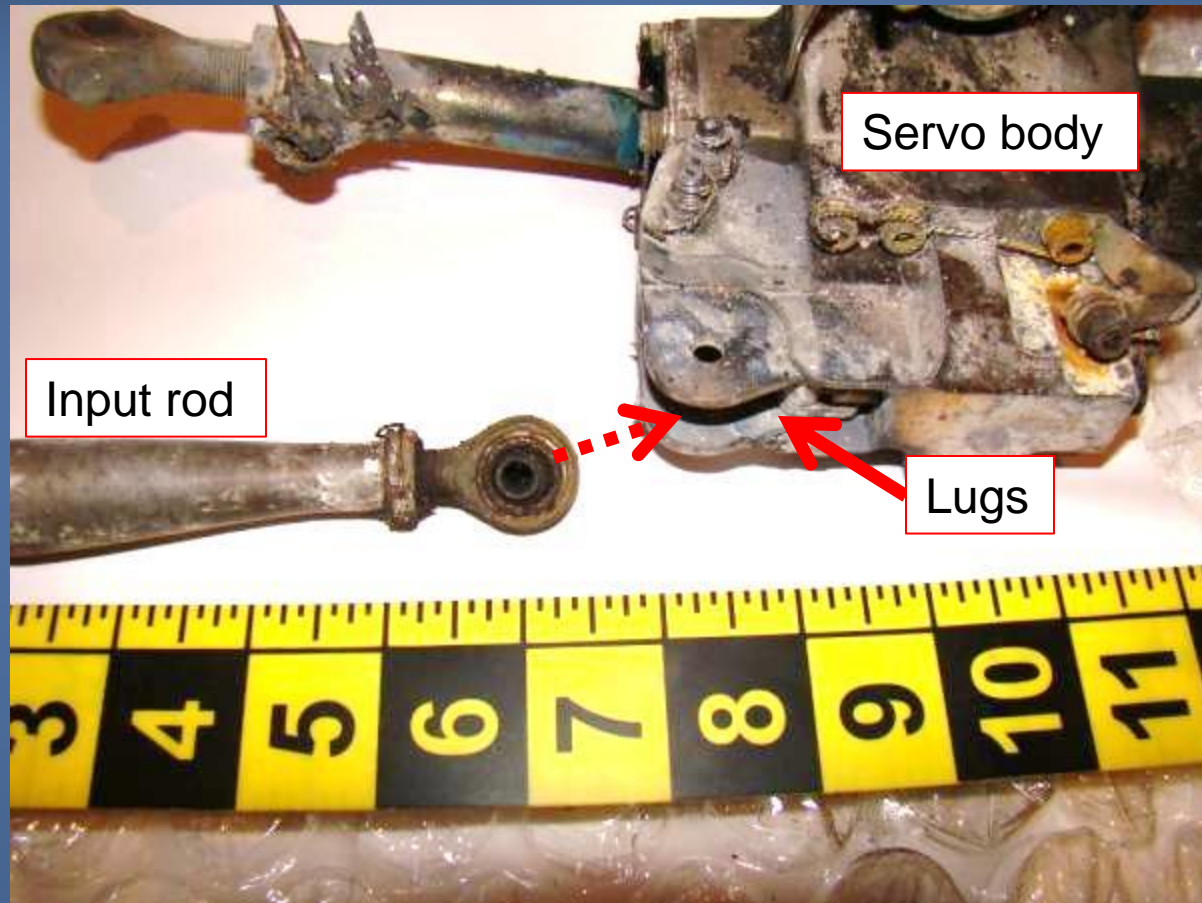
Initial Findings

- No evidence of non-standard flight
- No evidence of bird strike
- Altitude clear of terrain/obstacles
- Weather not a factor
- Fore/aft servo disconnected

Preflight Sequence

- 100-hour maintenance inspection
- Replaced fore/aft servo
- Flew maintenance check flight and two tour flights
- Accident on third tour flight, 3.5 flight hours after maintenance

Input rod and servo

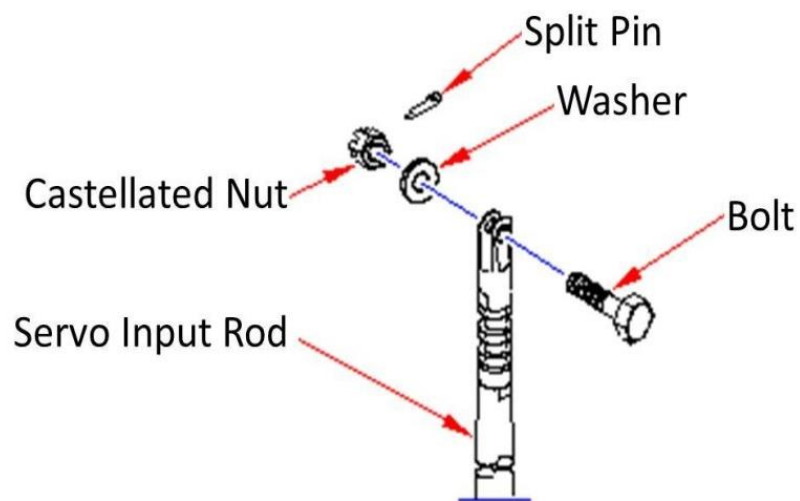


Fore/Aft Servo Installation

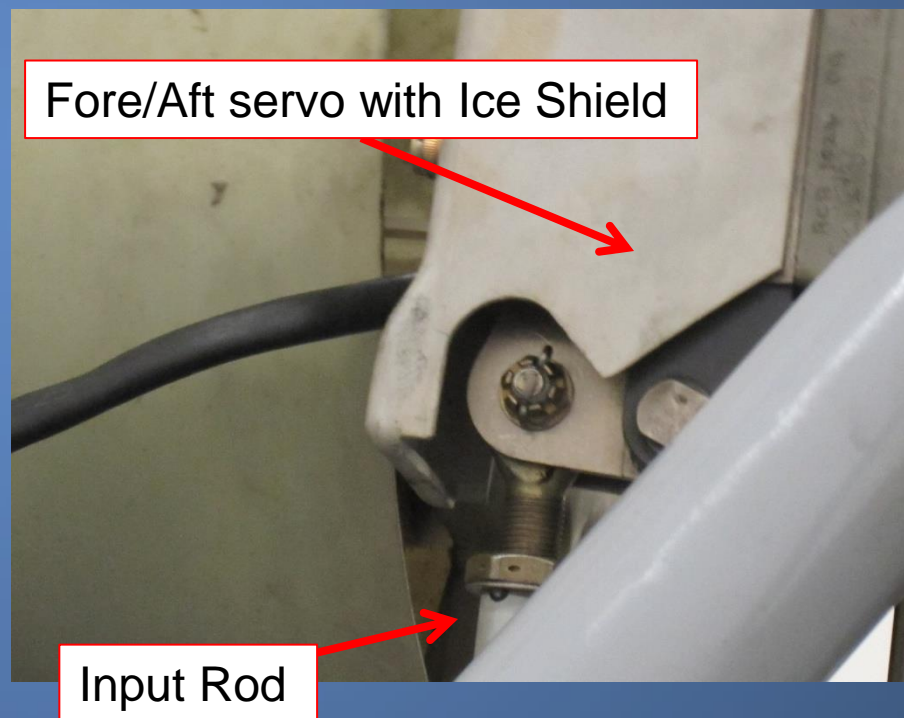
- Fore/aft servo replaced
- Fore/aft servo installation procedures:
 - Assess hardware
 - Connect servo to input rod
 - Torque nut
 - Install cotter pin
- Inspect installation

Hardware

Input rod hardware



Hardware installed

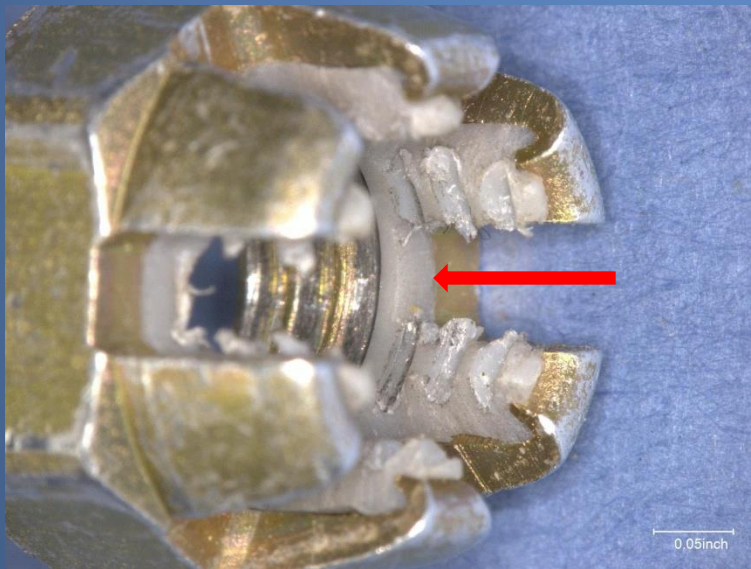


Bolt Loss Scenario

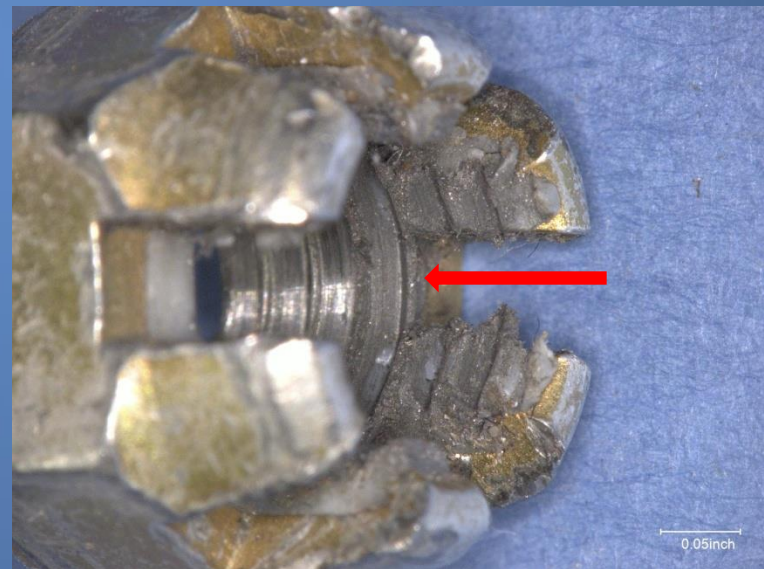
- Two locking devices
 - Self-locking nut
 - Cotter pin
- Self-locking nut most likely became separated from bolt

Self-Locking Nut

Acceptable Nut



Degraded Nut



Hardware Reuse

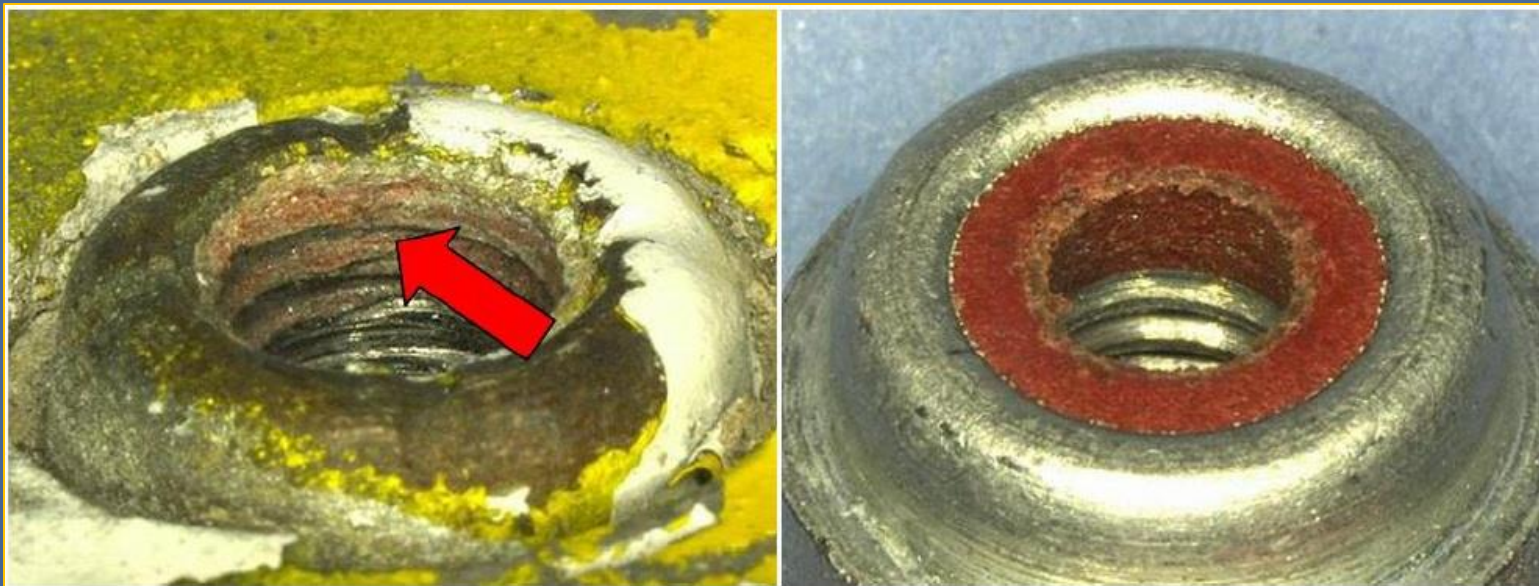
- Manufacturer's guidance: "If a nut can be easily tightened, it is to be discarded"
- FAA guidance: "DO NOT reuse a fiber or nylon lock nut if the nut cannot meet the minimum prevailing torque values"
- Fleet inspection of 13 helicopters: Half of self-locking nuts did not meet requirements

Self-Locking Nut Reuse (Reno)

Deteriorated self-locking nut was one “link in the chain” of P-51D crash in the 2011 Reno Air Races (note separated elevator trim tab)



Self-Locking Nut Reuse (Reno)



Inspection and Check Flight

- Mechanic and inspector completed inspection
- Maintenance check flight conducted
 - Corrected hydraulic belt tension
 - No flight discrepancies

Mechanic and QC Inspector

- Mechanic
 - 6 months at Sundance, 2 years in GA
 - All OJT - no previous helicopter training, experience
 - Sixth servo replaced
- QC inspector
 - 2 years at Sundance, 6 months QC
 - Previous incident: Chin bubble screws not tightened, perceived rush

Maintenance Issues

- Improper securing of the fore/aft servo
- Inadequate tension of the hydraulic belt
- Incomplete maintenance inspection

Mechanic, Inspector Fatigue

- Each typically worked 1200 to 2300
- Day before accident – each called in on day off
 - Mechanic: 0550-1846
 - Inspector: 0531-1855
- Mechanic had insufficient sleep
- Inspector had extended duty day

Maintenance Personnel Duty Times

Personnel	Normal Shift	Shift Originally Scheduled for December 6	Actual Schedule on December 6
Mechanic	Noon to 11:00 pm	Off duty	5:50 am to 6:46 pm
Inspector	Noon to 11:00 pm	Off duty	5:31 am to 6:55 pm

Maintenance Personnel Fatigue

- Effects of fatigue
 - Difficulty sustaining attention
 - Memory lapses
 - Performance errors

Work Cards: No Delineated Steps

- Documentation for 100-hour inspection
- Inspector signoff for overall fore/aft servo installation
- No specific signoffs for critical steps within task

Standard Sign Off

DISCREPANCY		CORRECTIVE ACTION	
No. 15	M/R F/A SERVO PN AC67246 SN RX 187 DUE O/H	RMVD M/R F/A SERVO SN RX 187 TSO: 1959.5 TSN: 14202.3. INST'D O/H UNIT SAME PN SN BX 264 TSO: 0.0 TSN: 21150.9. ALSO REPLACED ALL ORINGS PN 81810-110-24B7 PO 9048. REF AS 350 M/M CH 67	
Name	Date 12-6-11	Signature	Cert. No. Date 12-6-11 Insp
No. 16	T/R SERVO PN AC67032 SN FE 212 DUE O/H	RMVD T/R SERVO SN FE 212 TSO: 1959.5 TSN: 12328.4. INST'D O/H UNIT SAME PN SN DK287 TSO: 0.0 TSN: UNK. ALSO REPLACED ALL ORINGS PN 81810-110-24B7 PO 9048. REF AS 350 M/M CH 67	
Name	Date 12-6-11	Signature	Cert. No. Date 12-6-11 Insp
No. 17	Remove Arriel 1D1 Engine S/N <u>9399</u> Rental Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	Removed Arriel 1D1 Engine S/N <u>9399</u> Engine T.T. <u>11926.1</u> Total Ng <u>13996.03</u> . Total Np <u>15492</u> Reference AS350B2 AMM Chapter 71-11-00 Para 4-1. Engine tagged appropriately.	
Name	Date 12-6-11	Signature	Cert. No. Date 12-6-11 Insp
No. 18	Install Arriel 1D1 Engine S/N <u>9043</u> Engine T.T. <u>7400.0</u> Total Ng <u>2667.2</u> Total Np <u>7845.3</u> Rental <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	Installed serviceable Arriel 1D1 Engine S/N <u>9043</u> Reference AS350B2 AMM Chapter 71-11-00 Para 4-2.	
Name	Date 12-6-11	Signature	Cert. No. Date 12-6-11 Insp
No. 19	Clean the Air Duct.	Cleaned Air Duct ref. Arriel 1D1 MM 71-01-03-110-801-A01.	
Name	Date 12-6-11	Signature	Cert. No. Date 12-6-11 Insp

SDM-002 Revision: Original

Work Cards With Delineated Steps

Sample work card

DESCRIPTION		MECH	INSP
D.	Check trunnion bearings and drag brace bearing for proper installation and freedom of movement.		
3.	INSTALL NOSE LANDING GEAR - REFERENCE AMM		
→ A.	Support gear and jack with axle jack to insert trunnion pins in respective spherical bearings (13) on each side of the nose gear wheel well.		
→ B.	Jack gear to proper height and tap trunnion pin into place in each trunnion and trunnion support spherical bearing (13) then remove axle jack. NOTE: NOSE GEAR MUST BE LIFTED INTO POSITION WITH GEAR TRUNNION AXIS PARALLEL TO TRUNNION BEARING AXIS.		
→ C.	Ascertain that the trunnion pin lockpin holes are in alignment with mating holes in trunnion pin lockpins.		

Conclusions From Investigation

- Use of degraded self-locking nut
- Improper, or lack of, cotter pin installation
- Inadequate postmaintenance inspections
- Maintenance personnel fatigued
- Lack of specific signoffs for critical maintenance steps within tasks

Safety Recommendations

- Duty time limitations for maintenance personnel (A-13-01)
- Best practices for maintenance tasks, including work cards with delineated steps, especially for tasks involving safety-critical functions (A-13-02)
- [Note: Work cards are voluntary in Part 121 operations; hopefully Part 135 and 91 operators will also voluntarily use work cards.]
- Human factors training for maintenance personnel (A-13-03)

Human Factors Training

- Causes of fatigue, its effects, and countermeasures
- Fatigue education as part of a training curriculum
- Fatigue training is important because self-diagnosis of fatigue is not reliable
- No FAA human factors training requirement

Related Recommendations

- From ValuJet accident, 1996:
 - Review the issue of personnel fatigue in aviation maintenance; then establish duty time limitations consistent with the current state of scientific knowledge for personnel who perform maintenance on air carrier aircraft (A-97-71)
- Duty-time limitations should be based on
 - Start time
 - Workload
 - Shift changes
 - Circadian rhythms

Related Recommendations

- From ValuJet accident (con't):
 - Include, in its development and approval of air carrier maintenance procedures and programs, explicit consideration of human factors issues, including training, procedures development, redundancy, supervision, and the work environment, to improve the performance of personnel and their adherence to procedures (A-97-70)

Related Recommendations

- From air tour helicopter accident in Hawaii, 2007:
 - Establish and maintain a system for continuously analyzing the performance and effectiveness of inspection and maintenance programs (A-08-32)
 - Provide formal, model-specific helicopter maintenance training (A-08-33)

Related Recommendations

- From Beech 1900D accident in Charlotte, 2003:
 - Require Part 121 carriers to have procedures at the end of maintenance for a complete functional check of each critical flight system (A-04-08)
 - Require Part 121 carriers to implement comprehensive human factors programs to reduce the likelihood of human error in aviation maintenance (A-04-16)

FAA GA Maintenance Alert 121121

- Independent inspections of work
- Safety and security of components disconnected
- Look for the obvious; if there is a castellated nut, there is generally an associated cotter pin

FAA GA Maintenance Alert 121121

- Review and adhere to guidance regarding self-locking nuts
- Mark component or system if interrupted in the work process
- Cell phone policies
- Turnover briefings

FAA GA Maintenance Alert 121121

- Pilot check flights/review are last opportunity to detect potential safety hazards
- Review FAA human factors guidance and “Personal Minimums” Checklist

Safety Alert and Video

- Helicopter Safety Starts in the Hangar (SA-032, February 2014)
- Safety alert video produced by HAI
- [Note: Other maintenance-related NTSB Safety Alerts issued in 2013 include “Proper Use of Fiber or Nylon Self-Locking Nuts;” “Check Your Restraints;” “All Secure, All Clear;” “Mechanics-Manage Risks to Ensure Safety;” and “Armed for Safety: Emergency Locator Transmitters.”]

Want More Info?

- These issues and others covered in NTSB Safety Alerts
- SAs include hot links (or short urls) to find reports, dockets, other resources
- www.nts.gov



Maintenance Training Issues

- Does one size fit all?
 - Compare: Type ratings for pilots
- OJT
 - Effectiveness if trainer
 - Does not know how to train?
 - Does not enjoy training?
 - Is not good at training?
 - Need for training program approval or regulatory requirements?
- Simulators?
 - Not regulated
 - Use is increasing
 - Significant potential for improvement

Training Recommendations

- From CRJ accident in Philadelphia, 2008:
 - Require that mechanics performing required inspection item and other critical tasks receive on-the-job training or supervision until demonstrating proficiency (A-10-96)
 - Require that required inspection item (RII) inspectors receive supervision or on-the-job training on the proper inspection of RII items until demonstrating proficiency (A-10-97)
- From air tour helicopter accident in Hawaii, 2007:
 - Require air tour operators to provide formal, model-specific helicopter maintenance training for their mechanics (A-08-33)

Training Recommendations

- From Beech 1900D accident in Charlotte, 2003:
 - Develop detailed on-the-job (OJT) training requirements for Part 121 air carriers that rely on OJT as a maintenance training method. These requirements should include, but not be limited to, best practices, procedures, and methods for accomplishment and administration of the training (A-04-11)
 - Require that all Part 121 air carrier maintenance training programs be approved (A-04-15)

[Note: The FAA has put the air carrier maintenance training NPRM on hold indefinitely due to other higher priority projects.]

Conclusion

As aviation systems become increasingly complex, the industry must pay more attention to the human element of maintenance in order to continue improving safety



National Transportation Safety Board